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SPACE SHUTTLE

Solid Rocket Motors
Morton Thiokol, Inc.

Debris Prevention Analysis for DFI/OFI/OEI (STS-26 Configuration Only) Final Report

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Marshall Space Flight Center, Alabama 35812

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Debris Prevention Analysis for DFI/OFI/OEI
Final Report
(STS-26 Configuration Only)

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7/17/88
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7-15-88 Reliability	8/24/88 Data Management

CONTENTS

INTRODUCTION

The first 3 shuttle flights that use the Redesigned Solid Rocket Motors (RSRMs) will utilize Developmental Flight Instrumentation (DFI), as well as Operational Flight Instrumentation (OFI), and Operational Environment Instrumentation (OEI). The OFI consists of high pressure transducers which are used on both RSRMs to monitor the igniter and motor chamber pressure. DFI consists of assorted strain gages, temperature sensors, accelerometers, girth gages, and low level pressure transducers. These low pressure transducers are installed on the left hand booster to measure post-separation aerodynamic loading. OEI consists of temperature sensors. After flight 3, all DFI gages will be deleted, and only OFI and OEI will be used for subsequent flights.

This report deals specifically with debris prevention and hazards concerning the STS-26 flight DFI configuration only. Continued analysis is being done that will adequately address the debris hazards associated with the STS-27 and subsequent flight DFI configurations.

An analysis was performed by National Technical Systems (NTS), Saugus Division, evaluating any potential debris that could form as a result of any DFI/OFI failure. NTS report 525-3264-1, dated 12 April 1988, documents this analysis, and is included as Appendix A of this report.

Because the NTS analysis did not adequately cover the large DFI fairings, an additional analysis at Morton Thiokol was conducted on the forward dome accelerometer block. TWR-16362 documents this analysis.

RESULTS SUMMARY

A summary of the analysis results, as pertaining only to the STS-26 DFI configuration, is given below.

Analysis and testing was done by Morton Thiokol to determine the structural integrity of the accelerometer mounting block bonded to the forward dome. This is the only large DFI component on STS-26. The analysis showed positive margins of safety for the component and RSRM case (documented in TWR-16362).

Smaller DFI components were analyzed and reported in NTS certification reports 532-3198-2 (strain gages) and 523-3198-5 (resistance temperature devices). The potential to debond for these items is exceedingly small; a margin of safety of 49. If a debond were to occur, no debris hazard would exist because of the mass of the part and the constraining effect of the thermal protection system.

Analysis and tests indicate all DFI installations have positive margins of safety. The smaller components pose no debris problem because of size and containment. Acceptance tests now require pulling all larger components to identify any defective bonds. In the absence of defective bonds, the larger components pose no debris problems.

CONCLUSIONS

The analysis conclusion, as it relates to CPW1-3600A paragraph 3.2.6.5, is listed below.

CEI Paragraph	Planned Verification Effort	Conclusion / Verification Summary
Para. 3.2.6.5 Debris Prevention The SRM shall be designed to preclude the shedding of debris from the elements during pre-launch and flight operations that would jeopardize the flight crew and/or mission success.	ATV-8.0 Debris prevention analysis for DFI/OFI	Analysis results indicate no hazard to any part of the Space Transportation System (STS-26) configuration as a result of debris from DFI/OEI/OFI.

APPENDIX A

REPORT ON
DEVELOPMENT FLIGHT INSTRUMENTATION
DEBRIS PREVENTION

REPORT 525-3264-1

April 12, 1988

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Report 525-3264-1

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DEVELOPMENT FLIGHT INSTRUMENTATION DEBRIS PREVENTION

1.0 INTRODUCTION

The Development Flight Instrumentation (DFI) will be installed on the Redesigned Solid Rocket Motor (RSRM) for the first 6 flights. The DFI will include various strain gages, temperature sensors, accelerometers, girth gages, low pressure impact transducers, and high pressure igniter chamber and motor chamber pressure transducers. Some of these instruments are adhered directly to the motor case, skirt, and nozzle with adhesives, while others are installed in/or on fairings or housings which in turn are attached to the motor assembly with adhesives. Specific DFI components have been analyzed for safety of flight issues. Past flight data has been evaluated to ascertain adequacy of previous analyses. Available test data has been reviewed and similarity analyses performed for STS 26 through 31 configurations.

Safety of flight issues involve determining stresses in components during flight profiles, especially during preflight, ascent, and separation. Margins of safety are determined to ensure they are positive. If a potential for instrument debond occurs, an effect analysis is performed for that debond. Debonding or structural failure may produce debris which could damage the orbiter thermal protection system (tiles). The analyses also considers discontinuities caused by DFI component failures and the resultant stress increases.

2.0 SUMMARY

Each of the DFI components were analyzed and/or tested to determine structural strength and margins of safety. A finite element analysis was performed by National Technical Systems with and without the larger instrumentation housings and fairings. The finite element analysis showed acceptable stresses existed in the case after installation of the DFI components; all margins of safety were positive. The NTS finite element analysis was verified by an independent

Morton Thiokol analysis and report in TWR-17127, paragraph 2. Smaller DFI components were analyzed and reported in NTS certification reports 523-3198-2 (strain gages) and 523-3198-5 (resistance temperature devices). The potential to debond for these items is exceedingly small; a margin of safety of 49. If a debond were to occur, no debris hazard would exist because of the mass of the part and the constraining effect of the thermal protection system.

A family of adhesives are used in installing DFI components to the RSRM. All these adhesives have under gone tensile and shear strength tests. As the environmental temperature decreases the bond strength increases. Consequently, only maximum temperature profiles for the installed locations were considered. For structural adhesives, loads generated by motor operating pressures produced stress fields that masked the thermal environmental parameters.

Analyses and tests indicate all DFI installations have positive margins of safety. The smaller components pose no debris problem because of size and containment. Acceptance tests now require pulling all larger components to identify any defective bond. In the absence of defective bonds, the larger components pose no debris problems.

3.0 DISCUSSION

3.1 The Micro Measurements Group uniaxial and biaxial strain gages are installed at numerous locations on the RSRM. Gages are attached to the motor components with Micro Measurements M-Bond 200 adhesive. The gages are then coated with EC2216B/A adhesive which acts as a moisture barrier. The adhesive also provides some secondary structural support. Installations on the motor case are also covered by a cork thermal protection system which is adhered to the case by EA934NA adhesive.

3.2 NTS report 523-3198-2, Qualification Test Report for Uniaxial and Biaxial Strain Gages, in paragraph 4.1 addresses the debris prevention requirements. The installation exhibits positive margins of safety of 49.. Margin of safety was calculated by:

$$MS = \frac{\text{Installation Strength}}{(\text{induced stress})(\text{factor of safety})} - 1$$

Should a debond occur in the vicinity of the orbiter, the debonded part would be constrained by the thermal cork. Should an unlikely debond occur in the nozzle/skirt area, the part would be carried away by the exhaust plume. Should the part strike another part of the Space Transportation System, no damage would occur since the weight of the strain gage is less than one ounce.

3.3 Rosemount resistance temperature devices are installed at numerous locations on the RSRM. The devices are attached to the motor components with EA934NA structural adhesive. Both the sensors and the method of installation process have been used on previous flights. Previous missions used EA934 adhesives for the installation process. The EA934NA adhesives currently used are similar except the asbestos binder has been replaced with a silicone binder. The two adhesives exhibit similar strengths.

3.4 The scenarios presented for the strain gages apply equally to the RTD's. Paragraph 2.0 of NTS report 523-3198-5, Comparative Analyses of the Resistance Temperature Device, list the probability of a debond occurring as remote, margins of safety greater than 100. RTD's in the vicinity of the orbiter are covered by thermal cork as were the strain gages. In the unlikely event a debond would occur, the loose part would be restrained by the thermal cork. Should a debond occur in the nozzle throat area, the loose part would be carried away by the exhaust plume. Again, should a loose part contact a component of the STS, no damage would occur since the weight of the part is less than one ounce.

3.5 The girth gage used to measure circumferential growth of the motor case is a long wire strain gage. The adhesive used to attach the girth gage to the motor case is Micro Measurements Group GA-2. The theoritical structural strength is sufficiently high to provide comfortable margins of safety; tests are planned to determine a value. The gages on the motor case are coverd by the thermal cork in many areas. The girth gages are 36 gauge constantan wire which weighs less than an ounce per foot. Any debond that occurs would be of such minimal mass that no damage would occur.

3.6 The Operational Pressure Transducer and the igniter pressure transducer are installed on the forward dome of the RSRM. They are mechanically attached to the RSRM through pressure fittings. These transducers have been used on all previous STS missions. From a debris prevention discussion, the failure scenario must be different than a transducer becoming dislodged. A loss of a transducer would release hot combustion gases. This pressure seal has been tested to 5000 PSI, or 5 times MEOP.

NTS report 523-3198-1, Qualification Report for High Output Operational Pressure Transducer, provides the similarity analysis for the transducer. This report does not directly address debris prevention. All transducers are installed on the forward dome and are covered by a shroud. Should components of the OPT fail, i.e. the connector shell, and separate from the pressure seal, debris would not endanger STS components because of the shroud protection. Paragraph 5.25 of this NTS report reports the safety factors exceed 1.4.

3.7 The low pressure transducer is installed in a silica phenolic fairing, Morton Thiokol drawing number 1U82755. The transducer/fairing assembly contains a shear ply of EPDM rubber attached to the phenolic fairing with Chemlok 205 primer and 236 adhesive. The shear ply is then attached to the motor with EA934NA strucutral adhesive. All transducers are mounted at station 763.0 on the right hand RSRM. The transducer is connected via a pressure tube to the pitot fairing, Morton Thiokol drawing 1U82754. The materials and installation processes are the same as for the transducer fairing.

3.8 NTS report 523-3198-3, Qualification Report for the Low Pressure Transducer provides the similarity analysis for the transducer. For previous STS missions, these fairings contained a secondary bonding system. Current analyses in this report state this redundacy is not required. Paragraph 4.10 of the report lists positive margins of safety without the redundacy of 1.23. TWR-17127, paragraph 2.0 and 4.0 report similar analyses. Debond should not occur unless there is a defective bond during the installation process. An Acceptance Test, a pull test to a safety margin load of 30 LBF, has been recommended as a positive means of identifying defective bonds.

3.9 Two accelerometer mounting brackets are used on the RSRM. Morton Thiokol drawing 1U51216 is mounted on the forward dome. The accelerometer is mounted to the aluminum bracket and the bracket is attached to the forward dome with EA934NA adhesive. Table 10 of TWR-17127 shows a positive margin of safety of 1.67 for this installation. In the unlikely event a debond or component failure should occur, the debris would be contained by the shroud covering the forward dome preventing damage to other STS components.

3.10 Accelerometer mounting bracket 1U75611 is fitted with EPDM rubber shear ply attached with Chemlok 205 primer and 236 adhesive. The vulcanized bracket is then installed onto the motor with EA934NA structural adhesive. These installations occur at various points on the RSRM. A similarity can be made between this installation and other installations utilizing the EPDM. The RSRM system tunnel is an aluminum structure equippped with EPDM rubber and bonded with structural adhesive. These structures present margins of safety greater than 0.69.

3.11 NTS report 523-3198-4, Qualification Report for Cable Brackets, contains an analysis of safety factors for all cable brackets. The brackets are of nylon construction and are installed to the RSRM with EA934NA structural adhesive. Table 1 of the subject report lists factors of safety for these brackets from a minimum of 4.0 on the exit cone to a high of 9.07 for the heater cables. An acceptance test provides pull criteria to identify any defective bonds that may occur in the installation process.

4.0 CONCLUSIONS

Analyses and tests have been performed to document compliance with CPW1-3600A paragraph 3.2.6.5, Debris Prevention. DFI poses no debris hazard to the Space Transportation System.

TABLE 10
Stress Analysis Results

Component Material	Condition	Maximum Stress From Analysis (psi)	Factor of Safety Applied	Margin of Safety
RSRM Case Cylinder Section	20 °F, shear ply included	149,077 (Hoop)	1.4 ult. 1.1 yield	0.03 0.10
RSRM Case Forward Dome w/ Accelerometer Bonded	20 °F, No Shear Ply	53,416 (Hoop)	1.4	1.67
Bonding System	20 °F 75 °F	168 (Radial) 118 (Radial)	2.0 2.0	0.67 0.09
Fairings - Silica Phenolic	20 °F	1,727 (Hoop)	1.4	1.03
Housings - Aluminum	75 °F, No shear ply	17,319 (Hoop)	1.4	0.73
EPDM	75 °F	118	1.4	12.01

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Table 1. Cable Bracket Safety Factor Summary

Location	Drawing No.	Max. Flight Stress (psi)	τ_{ult} (psi)	S.F.	Max. Reentry/Splashdown (psi)	τ_{ult} (psi)	S.F.
Heater Cable Bracket (metal)	1U75810 1U75956	76.71	1830	23.86	38.4	370	9.64
Forward Dome (nylon)	1U50767	6.65	370	55.6	-	-	-
Aft Dome (nylon)	1U50767 1U75197	108.84	1830	16.81	70.11	370	5.28
Fixed Housing (nylon)	1U50767 1U75197	104.5	1830	17.51	87.62	370	4.22
Exit Cone Housing (nylon)	1U50767 1U75197	91.56	1830	20.0	92.0	370	4.02
Fixed and Exit Cone Housings (metal, TWR-13354)	1U52354 1U75245 1U75198	272.0	2000	7.35 (MS = 4.88)	-	-	-
Fixed and Exit Cone Housings (metal clamps, TWR-13354)	1U75245 1U75198	175.1	1200	6.85 (MS = 4.48)	-	-	-

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